

Review

Consumer perception, facts and possibilities to improve acceptability of health and sensory characteristics of pork[☆]

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Received 25 August 1998; received in revised form 4 March 1999; accepted 6 March 1999

Abstract

Changes at consumer level, as well as an image decline of the meat sector, resulted in considerable decreases of fresh meat consumption. Consumer orientation is considered as a prerequisite to slow down or reverse the adverse fresh pork consumption evolution. Consumer perception of pork is taken as the starting point of this article. Focus is first on assessing differences between facts related to nutritional value and healthiness aspects of pork and their perception by Belgian meat consumers. Second, possibilities of improving pork characteristics are identified. Pork is perceived worst as compared to beef and poultry on the attributes leanness, healthiness, taste and tenderness. Consumer-oriented response strategies should focus at improving these intrinsic quality characteristics, before other elements like traceability, labelling or marketing can be implemented successfully. The possibilities to improve nutritional value, healthiness and sensory characteristics pertain to selection, pig diet composition, transport, slaughter and post-slaughter circumstances. A successful adoption of consumer orientation urges for co-operation throughout the entire pork production chain. The identified topics are key attention points for adequate production and marketing by the pork sector, as well as for consequent communication by government and public services. © 1999 Elsevier Science Ltd. All rights reserved.

1. Introduction

Fresh meat consumption in present times is depressed by several phenomena. First, at the level of the individual consumer, increasing concerns about and requests for healthy and safe food, as well as growing environmental and ethical concerns are noticed (Steenkamp, 1997; von Alvensleben, 1997). This trend at consumer level is not typical for meat, but pertains to all sectors in food and agribusiness. A second phenomenon has specifically to do with the meat sector: accidents, scandals, and product safety incidents throughout Europe attracted negative media attention and damaged the sector image. Additionally, changes in consumer tastes and preferences (Burton, Dorsett, & Young, 1996; Rickertsen, 1996; Young, 1996) have led to a decrease of fresh meat consumption and strong competitive pressure on the meat industry. Coping with the aforementioned changes,

requires adequate response strategies. An efficient transmission of the changes at consumer level to the preceding stages which supply raw or intermediate materials is recognised as a prerequisite for success (Boehlje, 1996). Kohli and Jaworski (1990) state that agribusiness companies must become more market-oriented in order to be successful in today's increasingly competitive and saturated markets. This implies that a consumer focus should be the central element in their strategy, since it is the consumer who ultimately decides what kind of food product to buy (Steenkamp, 1987).

Several attempts to restore the confidence of the consumer and the image of the meat sector have been undertaken. Empirical evidence of potential success is available in literature for a large diversity of strategies. Gao and Spreen (1994) indicate that measures such as advertising, education programs, or grading and packaging changes may need to be undertaken in order to prevent a further contraction of the meat industry. Related and other strategies include the setting up of traceability systems (Ruffieux, Valceschini, & Viruega, 1998; Timon & O'Reilly, 1998; Viaene & Verbeke, 1998), as well as meat branding and labelling (Alvarez &

[☆] Communication No. 1077 of the Department Animal Nutrition and Husbandry.

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Alvarez, 1998; van Trijp, Steenkamp, & Candel, 1997; Verbeke & Viaene, 1999a in press), product development (Grunert et al., 1997; Schleyerbach, 1997), or communication through generic or brand advertising (Brester and Schroeder, 1995; Strak et al., 1997; Ward & Lambert, 1993). In some way these tools relate to aspects of marketing management and are mainly linked to extrinsic product quality cues (Olson, 1972), except for product development. However, evidence suggests that intrinsic cues (cues that are part of the physical product) usually carry more weight in the formation of quality expectations by consumers than extrinsic ones (Steenkamp, 1989; Steenkamp & van Trijp, 1996). Consumers need first to be entirely satisfied with the sensory properties of products, before other quality dimensions become relevant (Chambers IV & Bowers, 1993; Issanchou, 1996; Touraille, 1992). This idea is also supported in basic marketing literature, where “product” is described as not just one, but perhaps the most important element of the marketing mix (Baker, 1996; Kotler, 1996). Specifically related to communication and the spreading of product information, Chang & Kinnucan (1991) stress the importance of considering strategies that minimise the probability of exposure to negative information in the first place.

This paper concentrates on pork consumption, pork perception, facts and possibilities to improve pork acceptability through influencing health and sensory characteristics. Results of primary consumer research are integrated with a review of facts and potential product and process modification strategies throughout the pork chain in Belgium. Fig. 1 illustrates the structure of the paper. Consumer perception of pork and its main fresh meat substitutes beef and poultry are quantitatively

assessed on the attributes “leanness”, “healthiness”, “taste” and “tenderness”. Consumer perception is considered as the starting point and rationale for this paper since perception of health- and sensory-related attributes constitutes an important dimension of the acceptability of food (Cardello, 1994). Better perception possibly results in a better acceptability, a more favourable attitude, preference and increased consumption of the concerned product. Reference is made to Issanchou (1996) for a comprehensive overview of consumer perception with respect to meat and to Verbeke and Viaene (1999b in press) for a more detailed analysis and discussion of the consumer survey results. Second, based on our own research and a review of relevant literature, facts and figures that relate to health and sensory characteristics of pork are presented. A perception filter is held responsible for potential bias between facts and their perception by consumers (Wierenga, 1983). It is recognised that consumers may evaluate product attributes differently from experts (Kramer, 1990), or that consumer evaluations and perception may be in conflict with scientific indicator criteria (Den Ouden, Nijsing, Dijkhuizen, Huirne, 1998). Third, strategies that pertain to different stages throughout the pork production and processing chain are evaluated on their ability to improve pork characteristics (the facts), and further pork perception and acceptability in the future. The insights gained from this paper include implications and provide guidance to the pork sector in making decisions related to consumer-oriented product development and appropriate pork marketing, with the ultimate goal to slow down or reverse the image decline and the unfavourable consumption evolution that has occurred during recent years.

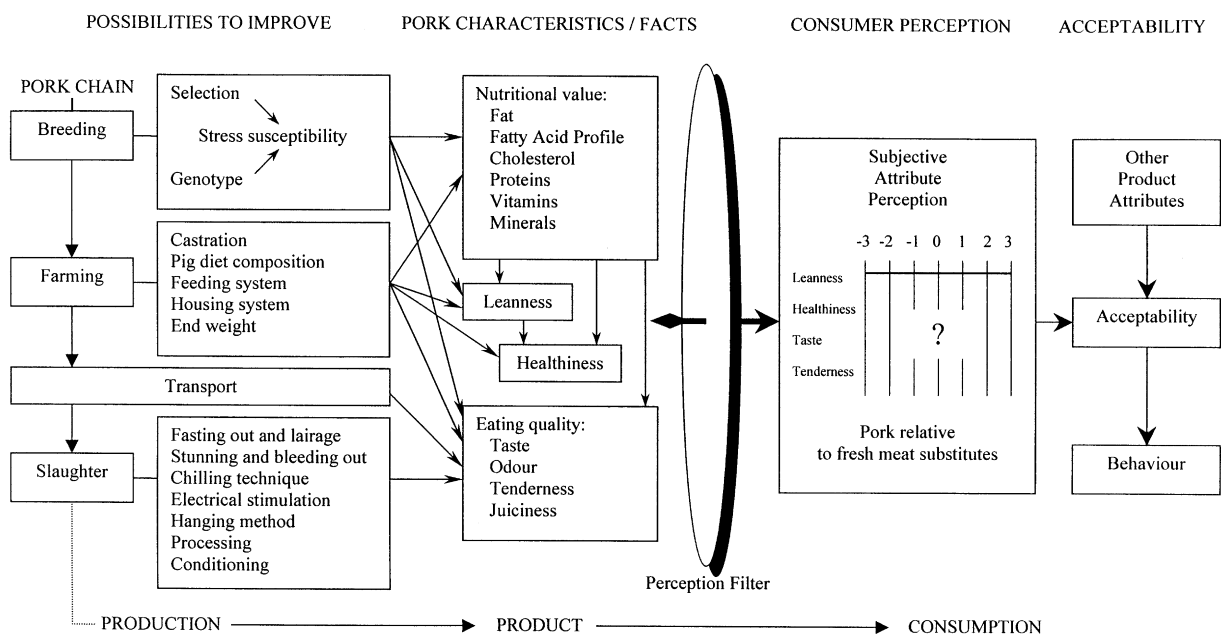


Fig. 1. Structure of the paper: possibilities to improve characteristics, consumer perception and acceptability of pork.

2. Consumption and consumer perception

2.1. Research methodology

Both secondary and primary data sources, related to consumption and consumer perception of meat in Belgium, are used. The secondary data include figures that illustrate the evolution of meat consumption. Primary quantitative data are gathered through a survey among meat consumers in Belgium. The fieldwork of the survey was organized in April 1998. The period of three years before the survey is characterized by considerable negative media attention to meat quality and safety, as well as by continuous, but cautious attempts by the meat sector to restore consumer trust. The consumer survey included 320 personal interviews, of which 303 were used for analysis. The market research was conducted using a non-probability quota sampling method (Malhotra, 1996), with age and sex of the respondents as quota variables (Table 1). Sample elements or respondents were selected based on convenience or judgment sampling. Women are slightly over-sampled, which is reasonable in food-related consumer research since they constitute the larger part of the persons responsible for food purchases. The sample is almost equally spread over four age categories. The survey instrument consisted of a questionnaire, including closed end questions, with answering categories based on preliminary literature review and qualitative exploratory research (Verbeke & Viaene, 1998a,b). The items pertaining to consumer perception of “leanness”, “healthiness”, “taste” and “tenderness” were accompanied by a 7-point semantic differential scale with end points associated with bipolar labels (Churchill, 1983; Malhotra, 1996; Pinson, 1983; Van Kenhove, 1995). The questionnaire was pre-tested, modified and refined before entering the fieldwork. The data were analyzed by means of SPSS (1997). First, a two-stage GLM-procedure is used to evaluate differences among mean attribute scores for pork, beef and poultry meat. The differences among specific means are evaluated through Tukey’s honestly significant difference (*Tukey HSD*)

multiple comparison test. Second, the chi-square statistic is used to test the statistical significance of observed associations between pork perception and respondent characteristics in cross-tabulations. The respondent characteristics are age, gender, education level, place of living, and meat consumption frequency. Unless explicitly mentioned, the decision rule for statistical significance is set at p -values lower than 0.05.

2.2. Consumption evolution

The supply balance sheets of the Centre for Agricultural Economic Research (LEI, 1997) indicate that total meat consumption in Belgium, expressed in kg carcass weight per capita, almost doubled during the previous 40 years. The increase is clear till the beginning of the 1980s, but stagnation is perceived during the last 15 years. Important shifts are remarked between meat from different species during the last decades. Apart from some fluctuations, pork consumption increased from year to year since 1965. The consumption of poultry meat was even more successful. Since 1995, poultry takes second place at the expense of beef consumption. Beef and veal consumption increased systematically till 1974, decreased during the period 1974–1988, stabilised till around 1993, and finally further decreased during recent years. Despite the apparent favourable long-term evolution of fresh meat consumption expressed in kg carcass weight *per capita*, a less favourable evolution of household pork consumption is noticeable in recent years. Fig. 2 depicts the evolution of the monthly per capita household consumption of pork, beef and poultry meat in Belgium during the period 1995–1997. The consumption of each of the considered fresh meat types fell considerably. Beef consumption fell 18% over the period 1995–1997. Pork and poultry meat consumption fell 7 and 8% respectively over the same period. Consumption trend equations were estimated by means of ordinary least squares (OLS)-regression. The coefficients on the time trend are negative for the three meat types, but only significantly different from zero for beef ($p=0.004$). The p -values for the coefficients in the pork and poultry equation are, respectively, $p=0.158$ and $p=0.427$.

2.3. Survey results and discussion

Significant associations are found between attribute perception of pork and respondent characteristics. Daily meat consumers judge pork taste better than less frequent consumers of meat ($x^2=11.942$; $p=0.018$). Urban consumers judge pork healthiness ($x^2=17.580$; $p=0.025$) and pork tenderness ($x^2=18.160$; $p=0.020$) significantly lower than consumers who live in rural areas. No significant associations between the perception of pork leanness and any of the respondent’s characteristics, neither between respondent gender and any of the considered pork attribute perceptions are found.

Table 1
Respondent characteristics of the consumer survey ($n=303$)

	Male		Female	
	<i>n</i>	%	<i>n</i>	%
<i>Age groups</i>				
< 30 years	35	27.1	44	25.3
31–40 years	32	24.8	40	23.0
41–50 years	28	21.7	48	27.6
> 50 years	34	26.4	42	24.1
Total	129	100.0	174	100.0
	42.6%		57.4%	

Descriptive profile analysis of the mean attribute scores leads to the conclusion that pork is perceived worst on the three sensory attributes, as well as on “healthiness” (Fig. 3). Table 2 includes the statistical validation of the perceived differences in attribute perception for the three meat types. Based on the *F*-tests, the null hypotheses of equality of mean scores are rejected for each of the four characteristics. The *Tukey*

HSD-tests reveal significant differences for all pair-wise comparisons of means, except for the mean attribute perception scores of poultry and beef on the attribute “taste”. The statistical validation confirms that pork has a significantly worse perception compared to both beef and poultry on each of the four included characteristics: “leanness”, “healthiness”, “taste” and “tenderness”, which greatly corroborates with earlier reported study results.

The aforementioned results are particularly relevant to the pork sector, given that the potential impact of the investigated attributes’ perception has been stressed by several authors. First, the “leanness” issue, its link to cholesterol and its relationship to health are considered to be one of the most important areas of consumer concern and scientific investigation (Capps & Schmitz, 1991; Pensel, 1997). The paramount and even growing prevalence of the leanness issue for red meats has been regularly reported during the last decades (Boland, Foster, & Akridge, 1995; Issanchou, 1996; McCabe, 1985). Second, Beardsworth and Keil (1991) and Richardson, Macfie, and Shepherd (1994) have pointed to “healthiness”, health benefits and risks as probably the most commonly acknowledged reason for reducing meat consumption. Findings by Khan, Teas, and Uhlenhopp (1995) corroborate our findings in that pork is perceived by consumers as being the least healthful meat alternative. Third, meat “taste” and flavour have regularly been indicated as promising characteristics for favourable future meat consumption decisions by consumers. Steenkamp, van Trijp and ten Berge (1994) identified taste intensity and taste evaluation along with fatness as key evaluative criteria for meat products. Richardson et al. (1994) pointed out that taste ranks traditionally high in terms of self-rated importance in food and meat choice decisions, as well as in studies of correlations between beliefs, attitudes and behaviour. Also, stronger attitudes to taste were found to be associated with increased meat consumption levels. Fourth, the importance and potential impact of “tenderness” on liking of specific meat cuts or overall meat acceptability has been reviewed by Issanchou (1996). The finding that pork scores significantly worse than its meat substitutes

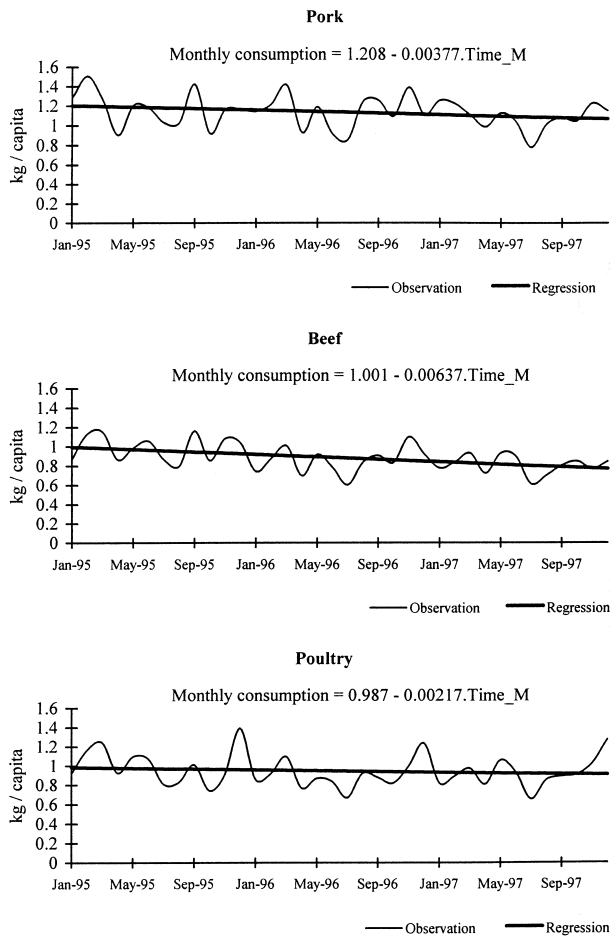


Fig. 2. Household consumption evolution of pork, beef and poultry during 1995–1997. Based on data from: GfK Belgium, 1998.

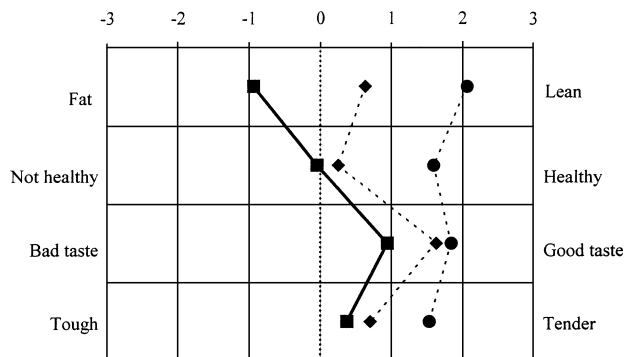


Fig. 3. Profile analysis of average fresh pork, beef and poultry attribute scores ($n = 303$) -■- = pork, -◆- = beef, -●- = poultry.

Table 2
Mean attribute scores^a for fresh pork, beef and poultry perception, ($n = 303$)

	Pork ^b	Beef ^b	Poultry ^b
Leanness ($F = 273.52$; $p = 0.000$)	-0.94a	0.63b	2.06c
Healthiness ($F = 114.94$; $p = 0.000$)	-0.05a	0.25b	1.59c
Taste ($F = 36.66$; $p = 0.000$)	0.94a	1.62b	1.84b
Tenderness ($F = 47.79$; $p = 0.000$)	0.37a	0.70b	1.52c

^a Mean attribute scores are calculated from a 7-point semantic differential scale.

^b Means in the same row with unlike letters are significantly different ($p \leq 0.05$).

on four important dimensions constitutes the cause and rationale for: first, reviewing facts and possibilities to improve pork perception and acceptability, and second, drawing conclusions and indicating implications with relevance to the future development of the pork sector.

3. Facts and possibilities to improve consumer acceptability of pork

3.1. Nutritional value and health aspects

Red meats like beef, pork and lamb are high in valuable and essential nutrients: high quality protein, niacin, vitamins B₁, B₂, B₃, B₆, B₁₂, iron and zinc (Table 3). Meat proves to be especially a good source of vitamin B₁₂, as vitamin B₁₂ deficiency can be a problem to vegetarians (Sanders & Reddy, 1994). Studies have also revealed that the meat avoiding part of the female population (especially adolescents) is at risk for iron deficiency (Ryan, 1997), which could be prevented by consumption of the readily available heme iron present in red meat (e.g. Leonhardt, Kreuzer, & Wenk, 1997). Meat also contains fat and to a minor extent cholesterol. These nutrients are in surplus in the typical Western diet with 40 energy% originating from fat, and hence have become major issues of health concern for the consumer. The cholesterol content of pork meat and even backfat, though, is far from being elevated. While butter contains 240 mg cholesterol/100 g, the contents in backfat and in lean pork amount, respectively, to 55 mg and 60 mg/100 g (Honikel & Arneith, 1996). This is in between the values of 44 mg and 84 mg/100 g obtained for respectively poultry breast and poultry leg without skin.

Contrary to cholesterol, fat in pork may be elevated depending on the meat cut or form in which the meat is eaten (unprocessed meat, minced meat preparations or meat products) (Table 4). Wood (1997) separated lean and fat and analysed the fat content of lean cuts from beef, lamb and pork purchased in supermarkets (Table 5). Lamb was revealed to contain most separable fat, followed by pork; whereas pork muscle or meat trim-

med from all visible fat contained only 2.2% ether extract (intramuscular fat, IMF), which falls within the 1.5–2.5% range found by Warmants, van Oeckel, and Boucqué (1996a) and Van Oeckel, De Boever, Warmants, and Boucqué (1997) for Belgian pork. Only poultry muscle is leaner than pork.

Besides the widespread belief that pork has high fat content, pork is often believed to have a saturated fatty acid (SFA) profile (Wright & Slattery, 1986). Ideally human fat intake should amount to maximally 30% of the daily energy intake, of which no more than 10 energy% should be originating from SFA, whereas 7 energy% can be obtained from polyunsaturated fatty acids (PUFA) (COMA, 1991), the rest being supplied by monounsaturated fatty acids (MUFA). The latter recommendations correspond with a PUFA/SFA ratio of 0.6–0.7. The degree of unsaturation of the fatty acids is important, since this can affect the development of cardiovascular diseases. These diseases have been linked to the balance of the LDL (Low-Density Lipoproteins) and the HDL (High-Density Lipoproteins) cholesterol or, respectively, the unfavourable and the favourable cholesterol. Saturated fatty acids, with less than 18 carbons, are LDL-cholesterol raising and HDL-cholesterol lowering; whereas MUFA and PUFA have, respectively, neutral to LDL-cholesterol-lowering effects and PUFA affect HDL-cholesterol positively. In addition to their cardiovascular beneficial role, PUFA are essential to the animal's metabolism. Especially, the PUFA linoleic (C18:2) and linolenic acid (C18:3) were found to be

Table 4
Fat content of various pork cuts and meat products

Cut	Fat (g/100 g)
Fillet ^a	1.6
Chop ^a	7.0
Chop, grilled, lean only ^b	11.0
Chop, grilled ^b	24.0
Leg, roast ^b	20.0
Leg, roast, lean only ^b	7.0
Ham ^c	5.0

^a Honikel and Arneith, 1996 (on a raw material basis).

^b Paul and Southgate, 1978.

^c De Schrijver, 1996.

Table 3
Nutritional value of red meats, in mg/100g

	Beef ^a	Pork ^a	Lamb ^b
Vitamin B ₁	0.08	0.80	0.10
Vitamin B ₂	0.24	0.27	0.20
Vitamin B ₃	4.60	5.60	4.10
Vitamin B ₆	0.33	0.35	0.10
Vitamin B ₁₂	0.004	0.0006	–
Fe	2.0	1.1	2.0
Zn	3.5	2.2	–

^a De Schrijver (1996).

^b NEVO (1989).

Table 5
Composition of loin steaks or chops

	Separable lean (%)	Separable fat (%)	Ether extractable fat (%) (in muscle)
Beef ^a	84	16	3.8
Lamb ^a	70	30	4.9
Pork ^a	79	21	2.2
Poultry ^b	–	–	1.7

^a Wood (1997).

^b Decker and Cantor (1992).

essential in that they serve as precursors for cell mediators (eicosanoids) and play a role in cell membrane fluidity.

Two families are distinguished within the PUFA, according to the position of the double bonds in the carbon chain: the (*n*-6) fatty acids, which are abundant in a lot of oilseeds, and the (*n*-3) fatty acids, which are characteristic for marine species (originate from plankton) and some plants (linseed). In animal fat the main representatives of the (*n*-6) and (*n*-3) series are, respectively, C18:2 and C18:3. Recently, recommendations by BNF (1992) stress the importance of the (*n*-6)/(*n*-3) balance within PUFA. The consumption of (*n*-3) fatty acids should be preferably increased at the expense of the (*n*-6) fatty acids, so that a (*n*-6)/(*n*-3) ratio of 6/1 is reached. As a response to the above-mentioned recommendations, eggs enriched in (*n*-3) fatty acids are marketed in e.g. Belgium and Germany. Aside from the beneficial role of (*n*-3) fatty acids in cardiovascular disease development (Bang and Dyerberg, 1972), they also have immunomodulatory and anti-inflammatory effects, partly mediated through the (*n*-3) fatty acid derived eicosanoids (Calder, 1996). Furthermore, the (*n*-3) fatty acids eicosapentaenoic [EPA or C20:5(*n*-3)] and docosahexaenoic acid [DHA or C22:6(*n*-3)] are essential for brain and retinal development and function (Beare-Rogers, 1988). In mammals, the latter fatty acids can be derived from C18:3(*n*-3); whereas arachidonic acid [C20:4(*n*-6)], serving as an eicosanoid precursor, is an important derivative of C18:2(*n*-6).

When comparing objectively the average fatty acid composition of pork fat (Table 6) with that of other domestic meat producing species, it appears pork is somewhere in between ruminants and poultry. Beef and mutton fat (tallow) have a more saturated profile, higher in myristic (C14:0) and stearic acid (C18:0), but lower in oleic (C18:1) and linoleic (C18:2) acid as compared to pork. Chicken fat is more polyunsaturated, being higher in C18:2 and lower in C14:0 and C16:0 as compared to pork. Furthermore, pork is particularly rich in oleic acid.

3.2. Possibilities to improve nutritional value and health aspects of pork

The discussion about the fatty acid profile of pork reveals that an increase of the PUFA content in pork fat at the expense of SFA would better meet the requirements of the health conscious consumer. Additional added value can be provided by enrichment in (*n*-3) fatty acids. Another possibility to improve the pork fat profile, from the consumer viewpoint, is to elevate the MUFA content of the pork fat, as the MUFA are supposed to play a protective role in cardiovascular disease development (Mattson & Grundy, 1985). The low incidence of cardiovascular diseases in the Mediterranean

Table 6

Fatty acid composition of common animal fats (in % of total fatty acids)^a

Fatty acid	Pork	Beef	Mutton	Chicken
C10:0	tr. ^b	tr.		
C12:0	0.1	0.1		0.1
C14:0	1.5	3.2	4.0	0.9
C15:0	0.1	0.6		
C16:0	25.3	25.5	22.6	22.3
C17:0	0.4	1.5		
C18:0	15.3	22.5	20.5	6.9
C20:0	0.2			
C14:1	0.1	0.5		
C16:1	2.6	2.8	2.4	6.0
C17:1	0.4	0.7		
C18:1	43.6	36.9	39.4	39.5
C20:1	0.9			1.2
C18:2	8.6	1.5	5.8	20.0
C18:3	0.6	0.6	2.4	1.3
C20:2	0.4			
C20:4				0.1
IsoFA ^c	0.5	3.1		
SFA ^d	43.5	56.4	49.6	31.5
MUFA ^e	47.6	40.9	42.6	47.3
PUFA ^f	9.6	2.1	8.2	22.1
PUFA/SFA	0.22	0.04	0.17	0.70

^a INRA, 1987.

^b tr. = traces.

^c IsoFA = iso-fatty acids and ante-iso-fatty acids.

^d SFA = saturated fatty acids.

^e MUFA = mono unsaturated fatty acids.

^f PUFA = polyunsaturated fatty acids.

area has been attributed to the intensive use of MUFA, originating from olive oil consumption.

Ellis and Isbell (1926) demonstrated that health aspects of pork can be enhanced since dietary PUFA are readily incorporated in the pig's fat stores. Warnants, Van Oeckel, & Boucqué (1996) and Van Oeckel, Casteels, Warnants, Van Damme, and Boucqué (1996); Van Oeckel, Casteels, Warnants, and Boucqué (1997) found a linear relationship between the feed PUFA content and the PUFA content of IMF (Table 7) and backfat in the pig, though with different efficiencies of PUFA incorporation in the two pig tissues. The slope of the regression represents the efficiency of incorporation. Incorporation in IMF occurs at a much lower rate than in backfat (Warnants et al., 1996b), yet there is a considerable dietary influence. Dietary MUFA incorporation in pork fat is less pronounced, as the pork fat MUFA level (predominantly oleic acid) of endogenous and dietary origin, is already elevated (almost 50%). Contrary to MUFA, PUFA in pork fat are exclusively of dietary origin, making a dietary enrichment in PUFA readily visible. The favourable deposition of PUFA in pork fat can furthermore be explained by the high digestibility of the PUFA and the fact that PUFA inhibit enzymes for synthesis and desaturation of other fatty acids (Nelson, 1992).

The extent of dietary PUFA and MUFA enrichment of IMF is demonstrated in Table 8. By incorporating oilseeds in pig feed, PUFA/SFA ratios in backfat around the dietary guideline of 0.6–0.7 can be easily achieved (Warnants, Van Oeckel, & Boucqué, 1998). However, this is not the case for IMF, where this ratio stays well below the values of 0.6–0.7. In contrast, the recommended $(n-6)/(n-3)$ ratio of 6/1, can be attained in IMF by feeding linseed. Concerning the incorporation of MUFA, the effect on IMF is hardly perceived, although high dietary MUFA levels (approximately 10% added MUFA rich oil) are fed. Hence, no additional health benefit can be expected from meat of pigs that were fed a MUFA rich diet. Anyhow, the figures show that the consumption of pork enriched in PUFA, whether of $(n-6)$ or $(n-3)$ origin can substantially contribute to a healthier fatty acid profile of the human diet. Moreover, meat is to be considered as a valuable source of $(n-3)$ fatty acids besides the widely recommended (fatty) fish which is often not prevalent in the Western diet (Specht-Overholt et al., 1997).

However, it should be noted that the incorporation of PUFA can have detrimental effects on the sensory and technological quality and acceptability of meat products (Houben & Krol, 1980; Stiebing, Kühne, & Rödel, 1993; Warnants et al., 1998). Unfavourable effects on fat firmness and oxidative stability are of concern for the meat processing industry. No disadvantages linked to the use of PUFA in pig feed with respect to animal performance or carcass quality (Van Oeckel, Casteels et al., 1997) are found. A rise in production costs is not to

be feared, since oils, oilseeds or oilseed meals are frequently used in pig feed with good economic results. Usually the fat content of commercial pig feed is limited to 5% crude fat, so that excess carcass fat deposition is avoided.

3.3. Possibilities to improve eating quality of pork

Intrinsic pork quality characteristics, such as leanness, taste, odour, tenderness and juiciness can be affected at different stages throughout the pork chain. Factors of influence include: first, selection, genotype choice and stress susceptibility at breeding level; second, production conditions such as castration, diet composition, feeding and housing system and end weight at farm level; and third, transport, and different pig and carcass handling techniques at slaughterhouse level. In this way a number of tools exist to change the intrinsic pork quality parameters and eating quality in certain directions. However, some modifications in favour of one parameter can imply negative effects on other parameters. For example, the production of more juicy and tender meat by increasing the IMF level in the meat, through using fatter breeds or higher slaughter weights, is accompanied by a deterioration of the leanness.

To get an idea of the incidence of non-acceptable eating quality of Belgian pork in terms of taste, tenderness and juiciness, a trial was conducted with taste panel testing of grilled loin from three commonly used pig crosses in Belgium. Selection and training of the panel was performed by a triangular test and a scale test with two pieces of grilled meat from the same muscle and one from another muscle. The tasters were asked to mark the identical samples and to score the meat from 1 to 8, from extremely bad to extremely good for taste, tenderness and juiciness. The eight most discriminating tasters formed the final panel. In each session, six panel members participated. Three pieces of meat from animals of the same sex and originating from the three genotypes (Pietrain boar x Belgian Landrace sow, Pietrain boar x

Table 7
PUFA incorporation efficiencies in intramuscular fat of barrows^a

Y-value	X-value	Equation	R ²
<i>Intramuscular fat</i>			
% C18:2	g C18:2/kg feed	$y = 0.26x + 5.37$	0.93
% C18:3	g C18:3/kg feed	$y = 0.22x + 0.15$	0.96

^a Warnants et al., 1996b.

Table 8
PUFA and MUFA enrichment of pork loin by PUFA/MUFA rich fat sources in the pig diet^a

Main fat source	Feed fatty acid content			Intramuscular fat			MUFA/SFA	PUFA/SFA	$(n-6)/(n-3)$
	% C18:1	% C18:2	% C18:3	% C18:1	% C18:2	% C18:3			
Tallow (control)	1.10	1.10	0.13	44.06	10.36	0.52	1.30	0.30	19.92
Rapeseed	2.58	1.47	0.33	46.55	10.54	1.11	1.39	0.32	9.50
Soybeans	1.40	2.47	0.31	38.75	14.98	1.04	1.01	0.37	14.40
Linseed	1.42	1.27	1.55	38.17	10.68	4.41	1.02	0.36	2.42
HOSO ^b	8.61	1.92	0.09	52.72	12.72	n.d. ^c	1.88	0.54	–
Safflower oil	6.49	1.75	n.d.	48.8	10.4	1.4	1.53	0.34	7.43
Dietary guidelines							≥1	0.6-0.7	≤6

^a Warnants et al., 1996a; Warnants et al., 1998; and unpublished results for PUFA, and Rhee et al., 1988 and Miller et al., 1990 for MUFA.

^b HOSO = high oleic sunflower oil.

^c n. d. = not detectable.

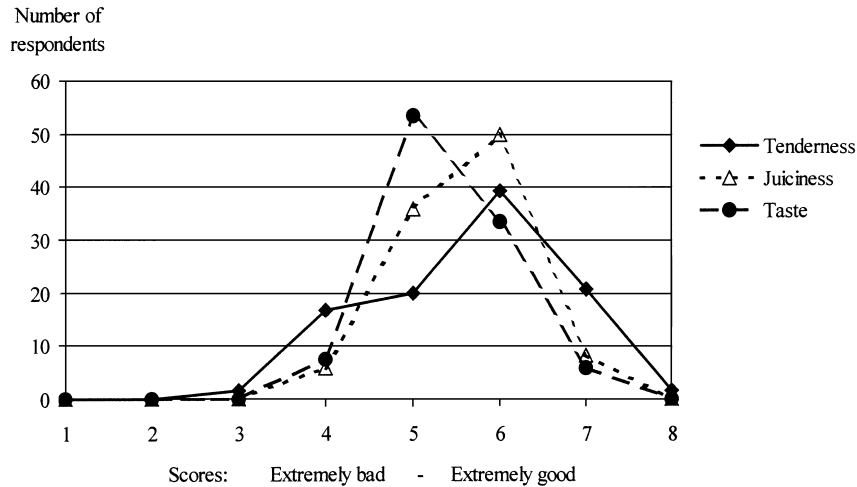


Fig. 4. Distribution of panel scores for grilled loin ($n = 120$).

Seghers hybrid sow and Pietrain boar x Large White sow) were grilled (Grill Major GR-103, Nova Electro International, Tongeren, Belgium) for 5 min until an internal temperature of about 74°C was reached. The panel scored each of the 120 samples for taste, tenderness and juiciness. The distribution of the scores (Fig. 4), pooled for the three pig crosses, shows that, respectively, 2 and 16% of the meat samples were scored as being very and moderately tough. Respectively, 2 and 21% were scored as being extremely tender and very tender. For juiciness and taste a much smaller dispersion of scores was noticed. Respectively, 6 and 8% of the meat samples were experienced as too dry and being tasteless, and 8 and 6% as very juicy and very tasteful. This implies both the incidences of unacceptable levels for juiciness, taste and tenderness, as well as strong variability for tenderness. Both unacceptable levels and a too large variability can be expected to have a negative impact on the repetitive purchase behaviour by consumers.

In the following sections, factors affecting the intrinsic pork quality will be discussed in detail by means of own experimental results and literature data. Four levels are distinguished: breeding, farming, slaughtering and preparing.

3.3.1. Breeding level

3.3.1.1. Selection possibilities. Lo, McLaren, McKeith, Fernando, and Novakofski (1992) reported heritability estimates (h^2) for pork tenderness, juiciness, flavour intensity, off-flavour intensity and overall acceptability of, respectively, 0.45, 0.12, 0.13, 0.03 and 0.34. So selection possibilities for a better pork quality concentrate especially on tenderness and overall acceptability. These results indicate that there is sufficient genetic variation to allow improvement in meat quality by selection, however, the bottleneck is that eating quality parameters can hardly be measured as part of pig improvement, but have to be measured by indirect

traits. One of the indirect traits is the IMF level. A positive relationship between the IMF level and the eating quality of pork was indicated by Kirkegaard, Møller, and Wismer-Pedersen (1979); Bejerholm and Barton-Gade (1986); Gandemer et al. (1990); Jakobsen (1992); and Moller and Iversen (1993); but not by Rhodes (1970); Göransson, von Seth, and Tornberg (1992) and Hovenier, Kanis, and Verhoeven (1993). The authors who found a positive relationship between IMF and eating quality properties, advised IMF levels from 1 to more than 4%, as presented in Table 9. The heritability of IMF is in the range of 0.4–0.6 (Cameron, 1990; de Vries, Hovenier, Brascamp, & Merks 1993; Hovenier, Kanis, Van Asseldonk, & Westerink, 1992; Lo et al., 1992; Schwörer, Blum, & Rebsamen 1986; Sellier, 1988; Touraille & Monin, 1982; Touraille & Monin, 1984). This indicates that it must be possible to modify the IMF content by selection, even within the genotype. Some studies (Sellier, 1988; Warriss, Brown, Franklin, & Kestin, 1990) even suggest that increased IMF levels can be achieved without making carcasses undesirably fat. However, Rhodes (1970), Bout, Girard, Runavot, and Sellier, (1989) and de Vries et al., (1993) found an unfavourable correlation between the IMF content and the lean content of the pigs, thus limiting

Table 9
Advised IMF levels for good pork eating quality

Authors	Advised %IMF
Møller and Iversen (1993)	Minimum 1% for acceptable eating quality
Bejerholm and Barton-Gade (1986)	Optimum 2–2.5% for tenderness and flavour
Kirkegaard et al. (1979)	
Jakobsen (1992)	Optimum 2–3% for sensorial meat quality
Gandemer et al. (1990)	> 4% for best tenderness, juiciness and flavour

selection perspectives for IMF. Correlations found by Casteels, Van Oeckel, Bosschaerts, Spincemaille, and Boucqué (1995) between the IMF level and daily gain and backfat thickness indicated that it must be possible to increase the IMF level by selection programmes, without negative consequences for the growth and backfat thickness of the animals.

3.3.1.2. Genotype. The genetic background of pigs explains a considerable part of the variation in meat quality (Casteels et al., 1995; de Vries, Van der Wal, Eikelenboom, Merks, 1992). Casteels et al. (1995) compared three genotypes for eating quality in a preference test. The results, presented in Table 10, show lower preference scores for taste intensity, tenderness and juiciness for the Belgian Landrace pigs, in addition to significantly lower IMF contents compared with the other two genotypes. Since the pig genotypes in this study were animals originating from a nucleus herd and, as such, results of pure pig selection lines, we conducted a new trial to evaluate meat from common used pig crosses in Belgium. The least square means of the three sensory descriptors per genotype were calculated and tested for significant differences (Table 11). Piétrain x Large White (PxLW) meat was evaluated as more tasty

than Piétrain x Seghers Hybrid (PxSH) meat, which in turn was more tasty than Piétrain x Belgian Landrace (PxBL) meat. The PxBL cross was evaluated as being toughest, while PxSH was somewhat, but not significantly more tender than PxLW. Juiciness was evaluated similar for the three genotypes. For PxBL, PxSH and PxLW, respectively, 42.5, 5.0 and 7.5% of the meat samples were experienced as too tough, 7.5, 2.5 and 7.5% of the samples as too dry, and 12.5, 2.5 and 0% of the meat samples as being tasteless.

3.3.1.3. Stress susceptibility. The meat quality characteristics of the Belgian pigs are closely related to the stress susceptibility (halothane gene) of the animals (De Smet et al., 1992; De Smet et al., 1995). The question arises if the selection for stress negative animals is sufficient to guarantee a good meat quality and acceptability by the consumer. It is thus important to know if the meat quality of a heterozygous crossbreed product (Nn) will not be inferior to that of the homozygous negative animal (NN) (Lundström, Essén-Gustavsson, Rundgren, Edfors-Lija, & Malmfors, 1989). A potential problem relates to the so-called PSE (Pale, Soft and Exudative) meat. PSE is a general accepted term for meat that is pale, loose in structure and showing loosely bound water (Van der Wal, Bollink, & Merkus, 1988). Standards are established for different instruments to identify PSE meat, but pH (acidity) measured 45 minutes post mortem (pH₁) is the most indicative measurement for PSE pork. Sellier (1988) summarised the results of eight different authors and concluded that even if the Nn-animals show in some studies an inferior pH₁-value (low values corresponds with bad meat quality) to that of the NN-pigs, this value is still above the critical threshold for PSE meat. Lundström et al. (1989) and Casteels et al. (1995) agreed that even if the problem of poorer meat quality still exists, the extent of the problem will be at least decreased by reducing the frequency of the halothane or stress gene. Besides improving daily gain and feed conversion ratio, one of the major goals of selection in the past was the improvement of carcass quality (in terms of lean meat content and conformation), because this is translated in a better price per kg carcass weight at slaughter. Unfortunately, selection for a better carcass quality has led to a higher incidence of the halothane gene in the Belgian pig population, and consequently in a worse meat quality (De Smet, van de Voorde, & Demeyer, 1997; De Smet, Verbauwhede, & Demeyer, 1994). During the last decades, not only economic factors, but also parameters that relate to meat quality are included in the selection goals.

Table 10
IMF levels and preference scores^a for tenderness, juiciness and taste intensity of three pig genotypes ($n = 81$)^b

	Belgian Landrace genotype ^c	Hybrids ^c	Large White genotype ^c
% IMF	0.89a	1.30b	1.18b
Taste intensity	1.72a	2.16b	2.12b
Tenderness	1.39a	2.31b	2.30b
Juiciness	1.59a	2.25b	2.18b

^a Eating quality was evaluated with a rank order test, giving a number from 1 to 3, from the worst to the best quality, by 4 panel members.

^b Casteels et al., 1995.

^c Means in the same row with unlike letters are significantly different ($p \leq 0.05$).

Table 11
Least square means of the eating quality^a parameters per genotype ($n = 120$)

	Piétrain x Belgian Landrace ^b	Piétrain x Seghers hybrid ^b	Piétrain x Large White ^b
Tastiness	4.51a	4.98b	5.32c
Tenderness	4.42a	5.51b	5.35b
Juiciness	5.07a	5.27a	5.02a

^a Eating quality of each sample was evaluated on a scale test by 6 panel members, giving scores from 1 'extremely bad' to 8 'extremely good'.

^b Means in the same row with unlike letters are significantly different ($p \leq 0.05$).

3.3.2. Farm level — production conditions

3.3.2.1. Castration. A general custom in pig rearing is to castrate the male pigs at an age of 3–4 weeks in order to

prevent the development of off-odour (boar taint) in the final meat. Growing entire male pigs for meat production creates however an economic opportunity, because they generally have more lean meat per carcass and show better feed conversion ratios than castrates (Bekaert, Casteels, Eeckhout, & Buysse, 1974; Van Oeckel, Casteels, Warnants, De Boever, et al., 1996). Additionally, animal welfare and the environment (better N-retention; Eeckhout, Bekaert, Casteels, 1971) can benefit from entire male production. Until 1992, the marketing of entire male pigs was not allowed in the European Union (EU). This has changed with EU-Regulation of (1991) (91/497), which permits (since January 1, 1993) intra-EU trade in meat from entire males that are free of boar taint and have a carcass weight below 80 kg. Unfortunately, boar meat production holds a risk for boar taint, which can displease the consumer and potentially results in a lower acceptability of pork. An experiment was conducted to evaluate the incidence of sensory aberrations for two common used breeds in Belgium (Belgian Landrace and Piétrain boar x Seghers hybrid sow). As presented in Table 12, 15 and 20% of the boars showed meat off-flavours and off-odours. However, 5% of the barrows and 5% of the gilts also showed meat off-flavours and 0% of the barrows and 5% of the gilts produced meat off-odours. The results for boar meat off-odours fit well with the conclusion of Malmfors and Lundström (1983). Based on studies in six European countries, they found that the proportion of consumers judging the odour of the tested boar meat to be less pleasant than that of normal pork varied from 5 to 35%. According to the same authors, this should be compared with 3–10% odour disfavours for meat tested from gilts and castrates, which is in accordance with the results presented in Table 12. Several authors proved that consumer acceptability for boar meat can be improved considerably after processing the meat into

meat products (Desmoulin, Bonneau, Frouin, & Bidard, 1982; Pearson, Ngoddy, Price & Larzelere, 1971; Malmfors & Lundstrom, 1983).

Nowadays, Great Britain, Ireland, Spain and to a limited extent Denmark produce boar meat while the other European countries only have a few percentages of entire males in their pig population. A number of reasons why the consumer in the first four countries accepts entire males are indicated. Malmfors and Hansson (1974) refer to lower slaughter weights. Other reasons include the use of other genotypes (linked with heredity of boar taint causing compounds: androstene and skatole and selection goals (Lundström et al., 1994; Willeke, 1993), the manner of raising the pigs (skatole content lowering methods: restricted versus ad libitum feeding (Malmfors et al., 1990), the use of wet versus dry feeding (Kjeldsen, Smed, Udesen, 1993), fasting versus non-fasting before slaughter (Maribo, 1992), scarce versus ample supply of water (Kjeldsen et al., 1993), a readily digestible protein source in the feed (Jensen, Cox, & Jensen, 1995), smaller sensibility to boar taint (Malmfors & Lundström, 1983; Malmfors et al., 1990) and the use of a screening method for skatole in Danish slaughterhouses (Vahlun, 1990; Kjeldsen, 1992). Until now, only a quick screening method for skatole has been developed, and no useful method for androstene is available. Meanwhile research proves that both compounds contribute significantly to boar taint (Bonneau, 1997).

In relation to the intrinsic cue leanness, entire male production, analogous to female pig production, has the advantage to create leaner carcasses than the castrated male pigs, as shown in Table 12 (Van Oeckel, Casteels, Warnants, De Boever et al., 1996a). However, this is accompanied by a reduction of 0.9% of the IMF level. A similar decrease of 0.4–0.8% in IMF content by not castrating the animals was reported by Malmfors and Nilsson (1978), Branscheid, Fisher, Kühne, Klettner, and Dobrowolski (1993) and Honikel (1993).

The objectively measured meat quality parameters: colour, paleness and water holding capacity were almost independent of sex in the studies of Van Oeckel, Casteels, Warnants, de Boever et al. (1996) and Van Oeckel, Casteels, Warnants, Van Damme, et al. (1996). This confirms observations by Casteels, Eeckhout, Bekaert, and Buysse (1974), Malmfors and Nilsson (1978), Judge and Harmon (1990), Branscheid et al. (1993) and Willeke, Raba, & Sick (1993). For the pork tenderness and juiciness, Wood, Jones, Francombe, and Whelehan (1986), MLC (1989) and Ellis, Webb, Avery, Smithard, Brown (1990), reported no significant differences between the sexes. Neither were flavour, pork odour intensity and overall acceptability influenced by sex in the study of Ellis et al. However, we recently found that barrow meat was experienced as being more tender, juicier and tastier than gilt meat (unpublished data).

Table 12
Meat off-flavours, meat off-odours, loin fat thickness, lean meat % and IMF content in function of sex and castration ($n = 60$)^a

	Boars ^c	Barrows ^c	Gilts ^c
Meat off-flavours ^b	15%	5%	5%
Meat off-odours ^b	20%	0%	5%
Loin fat thickness (mm)	13a	22b	15a
Lean meat (%)	60a	55b	59a
IMF (%) Average	1.5a	2.4b	1.4a
IMF (%) Range	1.0–2.6	1.4–3.8	0.9–1.8

^a Van Oeckel, Casteels, Warnants, De Boever et al., 1996a.

^b Meat off-flavours/off-odours by rank-order test: ranking for intensity of deviating taste or odour of three meat samples from a boar, a barrow and a gilt, by 12 panel members. Meat off-flavours/off-odours: % of the meat samples with a(n) taste/odour, deviating from one or both of the other samples within the same comparison.

^c Means in the same row with unlike letters are significantly different ($p \leq 0.05$).

3.3.2.2. *Pig diet composition.* Cromwell, Hays, Trujillo-Figueroa, and Kimp (1978) established that variation in dietary protein (12–20%) and energy (2900–3670 Kcal of metabolisable energy/kg) level had no effect on eating quality properties (tenderness, juiciness, flavour and overall satisfaction), although the IMF level and protein content of the meat changed. In an experiment of Mourot et al. (1993), water holding capacity (drip loss and cooking loss) could be improved by the incorporation of 5% glycerol in the pig diet, while meat colour and IMF level were not affected. D'Souza, Warner, Leury, and Dunshea (1998) demonstrated that dietary magnesium aspartate supplementation to pigs can be used to reduce the effects of preslaughter stress, possibly by reducing catecholamine secretion at slaughter. Consequently, the meat showed lower fluid losses, less paleness and a reduction of the incidence of PSE meat.

Although the use of hormones is illegal in the EU, some results are presumed concerning the effects on the sensory characteristics of pork. Porcine somatotropin hormone (of which the use is illegal in the EU) administration can lead to PSE meat development, although the average values fell within the normal range in a study of Aalhus, Best, Costello, and Schaefer (1997). Vestergaard and Oksbjerg (1995) summarised different studies on growth hormone treatment and concluded that there is no evidence that growth hormones have deleterious effects on objective quality parameters or sensory properties of pork (flavour, tenderness, juiciness, aroma, and overall acceptability), although the IMF level is reduced. However, high doses of growth hormone have caused a slight reduction of tenderness, juiciness and flavour intensity in some studies. For beta-adrenergic agonists treatment, Vestergaard and Oksbjerg reported only a minor negative effect on meat tenderness. Likewise, Warriss, Kestin, Rolph, and Brown (1990), who supplemented pig feed with 3 ppm salbutamol, found a better carcass quality without higher incidence of PSE meat; only tenderness was slightly reduced. Jeremiah et al. (1994) reported no effect of ractopamine on palatability and cooking properties, nor on consumer acceptance in a study on cured and uncured pork cuts. In a study of Bekaert, Casteels, and Buysse (1987), the inclusion of 1 ppm cimaterol did not affect the meat quality characteristics, although a reduced fat deposition and a higher muscle content were revealed.

Madsen, Østerballe, Mortensen, Bejerholm, and Barton (1990) report on the overall acceptability of pork, judged by a taste panel, as affected by dietary incorporation of relatively high levels of different feedstuffs, such as tapioca meal, skim milk powder, rapeseed (cake), (naked) oats and peas in a barley-soybean meal based diet of pigs between 50 and 100 kg. Overall acceptability of pork was not significantly influenced by the majority of treatments, except for the incorporation

of 45% peas and of 12% rapeseed, for which significantly poorer taste characteristics were obtained. For rapeseed, the inferior pork quality can be the result of the high level of polyunsaturated fatty acids.

A manipulation of the fatty acid profile by dietary means may also alter the sensory profile of the meat. In particular the sensory characteristic taste is of concern. Taste may be impaired by the occurrence of off-flavours, originating from the oxidative breakdown of unsaturated fatty acids. Phospholipids, which are proportionally abundant in IMF, are held predominantly responsible for the occurrence of the so-called warmed-over flavour (Igene & Pearson, 1979). The presence of the pro-oxidant heme iron in muscle, together with the highly unsaturated nature of the phospholipids in the muscle cell membrane, results in enhanced oxidative lipid breakdown. This process is aggravated by heating and results in a taste that is characteristic of preheated meat (roasts). Dietary PUFA incorporation in IMF, and thus in phospholipids, enhances the sensibility of the meat towards oxidation, especially when (*n*-3) fatty acids are envisaged. This was proven in an experiment of Ahn, Lutz, and Sim (1996) in which cooked loin, enriched in (*n*-3) fatty acids, showed decreased oxidative stability compared with the control as measured by the thiobarbituric acid test. Sensory scores, however, failed to indicate a difference between samples (Table 13). Likewise, Cannon et al. (1992) observed no difference in sensory properties of pork loin, enriched in PUFA.

Apart from off-flavours and off-tastes, originating from unsaturated fat oxidation products, fishy taints can persist in the animal product (Leskanich & Noble, 1997), due to fishmeal or fish oil feeding. Linseed provides an alternative, as it is less susceptible to oxidation than fish oil, to enrich the pork in (*n*-3) fatty acids. MUFA and PUFA enrichment, whether of the (*n*-6) or (*n*-3) series, has no deteriorating impact on the taste and the acceptability of meat that is either eaten immediately after purchase (Van Oeckel, Casteels, Warnants, Van Damme et al., 1996) or vacuum packed and stored for maximum six months at -18°C (Ahn et al., 1996) (Table 13). Ahn et al. (1996) stored meat loosely and vacuum packed in the freezer. Loosely packed meat showed inferior oxidative stability.

Contrary to fresh pork where few problems have to be expected when properly stored, meat products from PUFA enriched pork fat might suffer from taste aberrations, a higher frequency of dislikes and an impaired consistency, due to soft backfat (Houben & Krol, 1980; Stiebing et al., 1993; Warnants et al., 1998). An inferior consistency is often experienced when manufacturing dry fermented products, as the melted fat can drip out of the product during the drying or ripening phase, but can also become evident when cutting or slicing the meat product (occurrence of a fatty smear on the cutting surface of the knife) (Houben & Krol, 1980; Warnants et al., 1998).

Table 13
Sensory characteristics of MUFA or PUFA enriched pork loin

Authors	Fat source	Intramuscular fat			Meat consumption	
		% C18:1	% C18:2	% C18:3	Studied sensory characteristics	Result
Ahn et al., 1996	Linseed	32.5	15.4	12.3	Taste	Acceptable taste
Van Oeckel, Casteels, Warnants, Van Damme et al., 1996	Linseed	45.5	8.4	2.6	Taste, tenderness, juiciness	Acceptable taste, tenderness, juiciness
Rhee et al., 1990	HOSO ^a	52.7	12.7	n.d. ^b	Juiciness, tenderness, flavour, off-flavours, oiliness	Acceptable juiciness, tenderness, flavour, no off-flavours, no oiliness

^a HOSO = high oleic sunflower oil.

^b n.d. = not detectable.

When enriching the cured meat product more specifically with (*n*-3) fatty acids, off-flavours are likely to occur, unless shelf-life is reduced and supplemental antioxidant (vitamin E) is added. Incorporation of MUFA in pork fat for cured meat products does not seem to cause any problems in terms of consistency or taste (Myer et al., 1992); after all, oleic acid already makes up the biggest part of the pork fatty acid pattern.

The increased susceptibility to oxidation and off-flavour through enrichment of pork fat and meat with PUFA can be counteracted and delayed by raising the vitamin E level in pork tissues (Monahan et al., 1990; Monahan et al., 1992). Vitamin E, administered in the feed, is incorporated in cell membranes and thereby prevents oxidation of the unsaturated triglycerides and phospholipids. As a result of protection against oxidation, vitamin E incorporation (at a level of 200 ppm) improves sensory quality in terms of flavour freshness, tenderness and juiciness (Dirinck, De Winne, Casteels, & Frigg 1996). Another benefit is the lengthening of the shelf life of pork. Colour stability throughout storage is also positively affected by vitamin E supplementation (Asghar et al., 1991).

3.3.2.3. Feeding system. The feeding system has been proven to influence eating quality of pork in a study of Ellis et al. (1990). *Ad libitum* fed pigs produced more tender, more juicy and better overall acceptable pork than pigs reared under restriction. Seewer and Prabucki (1993) and Lebret, Lefaucheur, Mourot, and Nonneau (1996) found an indirect positive effect of *ad lib* versus restricted feeding on eating quality, mediated by a higher IMF level. *Ad lib* feeding however also led to more depot fat. Lister (1994) reported that the final phase of feeding immediately prior to slaughter is the most important in terms of tenderness. It is suggested that it is possible to enhance tenderness with a short burst of *ad lib* feeding prior to slaughter. However, short-term *ad lib* feeding improved tenderness not to the same extent as long-term *ad lib* feeding, but the short-term treatment was more advantageous in terms of feed efficiency and carcass leanness.

3.3.2.4. Housing system. Warriss, Kestin, and Robinson (1983) failed to prove any important difference in meat quality (pH, colour, water holding capacity) from pigs reared under two opposite forms of husbandry: one intensive, in bare concrete pens; the other one non-intensive, under environmentally enriched conditions in an outside paddock. Likewise, Gandemer et al. (1990), Van der Wal et al. (1993) and Dworschák et al. (1995) found no difference in pork eating quality and IMF level between free-range pigs and intensively reared pigs. In a study of Sather, Jones, Schaefer, Colyn, and Robertson (1997), the fattening environment did not substantially influence meat quality, but a trend towards higher PSE scores was noticed for outdoor as compared to confinement-reared pigs. Moderate indoor exercise of pigs from 22 to 103 kg did not affect meat quality characteristics after slaughter, as reported by Hansson et al. (1991). The hypothesis that pigs reared under more natural conditions would be easier to handle and less subject to stress during loading and transport prior to slaughter, with a positive effect on ultimate meat quality, is not supported by the above reported studies.

3.3.2.5. End weight. A factor of variation at slaughter is the final weight of the pigs. Candek-Potokar, Zlender, and Bonneau (1998) demonstrated that an increase in slaughter weight resulted in a higher IMF level and more intense colour. However, tenderness and chewiness of cooked pork were negatively affected. Seewer and Prabucki (1993) and Lebret et al. (1996) also found a higher IMF level at higher slaughter weights, but unfortunately, this strategy also led to more depot fat.

3.3.3. Transport and handling

Gentle transport to the slaughterhouse and suitable driving aids to the stunning point (Perremans & Geers, 1997; Troeger, 1991) are of considerable importance for good pork quality. Good transport conditions and gentle handling minimise the incidence of PSE meat, since less stress is experienced shortly before slaughter. These conditions are even more important if the involved animals are stress susceptible or if the transport occurs in hot

weather conditions, because pigs fail to eliminate heat from the skin (Guardia, Gispert, & Diestre, 1996). In a study of Grandin (1986), it was proved that significant improvements in meat quality can be achieved by the elimination of rough handling, by reducing or eliminating electric prod usage and by avoiding excessive physical exertion and excitement shortly before slaughter. Variation in loading density between 0.35 and 0.50 m² per 100 kg pig, had relatively little effect on blood welfare parameters or meat quality in commercial transports lasting less than 3 h (Barton Gade & Christensen, 1998). Instead, indications for an increased risk of skin damage due to trampling and/or fighting were apparent when more than 0.35 m² space per 100 kg pig was available during transport. Lambooy, Garssen, Walstra, Mateman, and Merkus (1985) and Lambooy and Engel (1991) concluded from experiments with long-term transport (respectively, 2 days and 25 h), that loading densities of approximately 235 kg per m² or 0.425 m² per 100 kg pig form an acceptable compromise between animal welfare, meat quality and the economic profitability of transport. This is also the loading density limit that is stated in the EU-Regulation (1995) (95/29), concerning the protection of animals during transport.

3.3.4. Slaughterhouse level

3.3.4.1. Slaughter date. De Vries et al. (1992) found that while 10–30% of the variation in intrinsic meat quality can be explained by heredity, slaughter date effects can explain another 10–25%. Although slaughter day reports were made, it remained difficult to explain the differences between the different slaughter days. Obviously coincidental factors during transport and in the slaughterhouse, that are difficult to identify and describe, are playing a key role.

3.3.4.2. Fasting out and lairage time. A feed withdrawal period of 16–24 h before delivery of the pigs at the slaughterhouse is recommended in practice. This is beneficial to the hygienic status of the carcasses and reduces the incidence of PSE meat (at 24 h fasting), implicating improved colour, water holding capacity and firmness of pork muscle (Eikelenboom, Bolink, & Sybesma, 1991). However, according to Jones, Rompala, and Haworth (1985), a too long fasting period prior to slaughter results in considerable carcass weight losses. Warriss, Brown, Edwards, and Knowles (1998) found that between transport and slaughter, a period of 1–3 h rest in lairage was optimal to recover from stress during transport and to reduce the incidence of PSE meat.

3.3.4.3. Stunning and bleeding out technique. The stunning method is another factor of influence on the sensory properties of meat (Troeger, 1991). Casteels et al.

(1995) compared meat quality properties of electrically stunned pigs (electrical pincers, 80V) with CO₂-stunned pigs. For pH₁ decrease rate and water holding capacity, CO₂-stunning performed best, but for colour properties better results were obtained with electrical stunning. In a study of Hölscher, Herthum, and Kalm (1989) no significant differences were obtained between CO₂-stunning and electrical stunning in terms of meat quality traits. The bleeding out technique is also of influence for pork quality (Troeger, 1991). If the carcasses are stuck immediately after stunning in the horizontal position instead of vertically while hanging, and bled out in the same horizontal position, the muscle contractions that occur are less energy-consuming and the resultant meat quality is better. Indeed, Woltersdorf and Troeger (1987) found improved meat quality traits (pH₁, drip loss, colour) when carcasses were electrically stunned followed by bleeding out in a lying position. Contrary, Hölscher et al. (1989), found that bleeding out in a lying position directly after CO₂-stunning did not positively influence meat quality. Faucitano, Marquardt, Oliveira, Sebastiani Coelho, and Terra (1997) reported a considerable reduction of the incidence of PSE meat as a result of the absence of electric goading along the stunning race, combined with higher voltages and lower current levels, a shorter stunning to stick interval [< 15 s as recommended by Anil (1991)] and debleeding in the horizontal position before shackling.

3.3.4.4. Chilling technique. With a simulation study, Van der Wal and Eikelenboom (1984) proved that an elevated muscle temperature in the early post mortem period can contribute to the development of PSE. Because of the negative effect of a high muscle temperature early post mortem, Monin, Lambooy, and Klont (1995) and Van der Wal and Eikelenboom (1984) recommend to limit the heat supply shortly before killing and early post mortem to a strict minimum in order to allow a fast decrease of the muscle temperature after slaughter. However, too low a temperature post mortem can induce cold shortening toughness in pork comparable to beef and lamb. Dransfield and Locker (1985) found that cold shortening toughness occurs in pork if the muscle temperature falls below 10°C within 3 h post-slaughter when sufficient energy reserves are present to induce contraction. Indeed, rapid chilling led to slightly shorter sarcomeres and tougher meat, suggesting a greater degree of cold shortening in rapidly chilled meat compared with conventionally chilled meat (Dransfield, Leswith, & Taylor et al., 1991; Taylor and Martoccia, 1995; Taylor, Perry, & Warkup 1995). Møller and Vestergaard (1987) found that *longissimus dorsi* muscles with a pH between 6.1 and 6.5 showed lower Warner–Bratzler shear force values when a 2 or 4 h delay was used before passing into a chilling tunnel (–28°C–22°C) compared with muscles without delay

before chilling. For samples with a pH between 5.7 and 6.1, the decrease in shear force values by using a delay time (2 or 4 h) before chilling was not significant. According to Van der Wal, Engel, van Beek, and Veerkamp (1995) ultra rapid chilling at high air velocity (-30°C during 30 min and 4m/s) results in an increased risk for cold shortening, and consequently tougher meat compared with conventional chilling ($+4^{\circ}\text{C}$, air velocity 0.5 m/s). Thus, musculature is affected by cold shortening if low temperatures are reached within the musculature before the onset of rigor mortis. On the other hand, Taylor, Nute, and Warkup (1995) found that a 3 h delay (at $>10^{\circ}\text{C}$) before chilling (at 1°C) had only a minor effect on the cooling rate of the *m. longissimus thoracis et lumborum* or the deeper *m. semimembranosus* compared to carcasses where chilling (1°C) commenced 45 min post-slaughter. Moreover, delaying the onset of chilling with 3 h gave no improvement in tenderness. Aslo in an experiment of James, Giegel, and Hudson (1983) no evidence of cold shortening in the form of reduced sarcomere lengths was found. Other meat quality characteristics, such as water holding capacity by filter paper method, drip loss and cooking loss, colour by Labscan II and Japanese colour scale, a six-point subjective quality evaluation (DFD-PSE) and a five-point marbling scale, were hardly influenced by the chilling regime (Van der Wal et al., 1995).

James et al. (1983) found lower evaporative losses and slightly darker meat after ultra rapid chilling (-30°C during 4 h and 1 m/s) compared with conventional chilling (0°C and 0.5m/s for 24 h). In an experiment of Taylor, Perry, and Warkup (1995) a rapid chilling procedure (air at -20°C and 1–1.5 m/s until deep muscle temperature $<10^{\circ}\text{C}$ for 2–3 h post mortem, followed by air at $+1^{\circ}\text{C}$ and <0.5 m/s until 24 h post mortem) resulted in a reduction of evaporative carcass weight loss of 0.5% over the 24 h period compared with conventional chilling (air at $+1^{\circ}\text{C}$ and <0.5 m/s until 24 h post mortem). Thus, a rapid reduction in temperature tends to move pork away from pale, soft and exudative meat.

In a study of Neel, Reagan, and Mabry (1987) flavour desirability, overall desirability, tenderness and shear force values were not affected by the chilling conditions (rapid chilling vs conventional chilling), but it must be noted that these treatments were linked with other processing conditions and cannot be interpreted independently. Jeremiah, Jones, Kruger, Tong, and Gibson (1992) proved that blast chilling (-20°C for 1, 2 or 3 h or -40°C for 1, 2 or 3 h) could effectively reduce carcass shrinkage and improve meat quality, without adversely affecting palatability or cooking properties within the context of the experimental conditions.

In addition to chilling temperature and chilling time, the use of high humidity air during chilling, is of importance. In an experiment of Giegel, Butler, and

Hudson (1989), chilling pigs in high humidity saved 0.2% in weight loss over 24 h when compared with conventionally chilled pigs (relative humidity of 97–98% vs 92%). Similarly, the use of an intermittent water spray for the first 6 h of the cooling cycle had a dramatic effect on weight loss, demonstrating that most weight is normally lost during this early period of chilling when the temperature difference between the carcass surface and the air is high (Giegel et al., 1989).

3.3.4.5. Electrical stimulation (ES). The purpose of ES is to deplete energy reserves, to prevent cold shortening as a result of the chilling process and finally to produce tender meat. Taylor, Perry, and Warkup (1995) found that, under conventional chilling conditions (air at $+1^{\circ}\text{C}$ and <0.5 m/s until 24 h post-slaughter), high voltage ES (700V, 12.5 Hz for 90 s) at 20 min post-slaughter could overcome cold shortening toughness of pig carcasses and consequently improve the tenderness as evaluated by taste panel. Similarly, Giegel and James (1984) found that ES (700 V, 25 Hz during 10 ms), immediately after bleeding, produced more tender pork under conventional chilling conditions (air at 0°C , 1 m/s for 24 h). Furthermore, Giegel and James (1984) found that the toughness in meat that was subject to ultra rapid chilling (air at -40°C and 1 m/s for 80 min, followed by 0°C and 0.5 m/s for 130 min) can be completely eliminated by ES. However, the high voltage ES treatment can induce a rapid fall in pH, resulting in slightly paler and more watery meat (Dransfield et al., 1991; Giegel and James, 1984; Taylor, Perry, & Warkup, 1995).

Neel et al. (1987) found reduced juiciness ratings for electrically stimulated pork (550 V for 30 s (2 s on, 1 s off)) within 10 min post-slaughter, compared with non stimulated pork, while flavour desirability, overall desirability, tenderness and shear force values were independent of ES treatment. Taylor and Martoccia (1995) compared the effectiveness of low voltage ES (85 V, 14.3 Hz for 64 s) with high voltage ES (700 V, 12.5 Hz for 90 s). They found that low voltage ES, applied immediately after slaughter, improved tenderness over unstimulated controls, even when the latter were conventionally chilled. The low voltage ES was found not to be as effective as the high voltage ES. According to Taylor and Martoccia (1995) and Taylor and Tantikov (1992), stimulation within 5 min post-slaughter, particularly with high voltage, increased drip from the *m. longissimus thoracis et lumborum* up to an excessive amount which would certainly discourage the use of this ES practice. In contrast, delaying the ES until 20 min post-slaughter resulted in a pH fall less pronounced and a decreased drip loss from *m. longissimus thoracis et lumborum*. Taylor and Tantikov (1992) concluded that there exists a potential advantage of ES (high voltage, 20 min post-slaughter) combined with rapid chill

treatment over conventional chilling and no ES, especially for high value loin cuts. In this way the disadvantage of a higher drip loss by ES can be largely overcome by the rapid chilling.

3.3.4.6. Hanging method. Because of the mechanical tensions which occur in both the shackled and the “free” side of a shackled carcass, Aalhus, Garipey, Murray, Jones, and Tong (1991) conducted an experiment to compare the effects on ultimate meat quality of non-shackling (prone) and shackling of carcasses immediately after stunning (with head-to-back electrodes, 700 V for 2–3 s). The results indicated that shackling had an effect on post mortem muscle metabolism, although the resultant effect on meat quality was minimal. They advised to shackle carcasses on the opposite side to which stunning was applied to ensure a good meat quality. Furthermore, altering the method of carcass suspension during chilling can affect muscle shortening and consequently tenderness of the meat. If a carcass is suspended by the pelvis (from the *obturator foramen*) instead of by the *achillus tendon* during chilling, some of the loin and hindquarter muscles are more stretched. The longer sarcomeres which results from this stretching are associated with increased tenderness (Møller & Vestergaard, 1986; Taylor, Perry, & Warkup, 1995).

Cooking loss was not influenced by the suspension method in the work of Møller and Vestergaard (1986). Smulders, Van Laack, Mestrusty, and Jennissen (1992) found that pelvic suspension (hip-suspension combined with limb-weighting) resulted in lower drip and cooking losses, reduced Warner-Bratzler shear force values and markedly higher panel tenderness ratings. In addition, the treatment resulted in a 3% higher processing yield when various ham muscles were processed as cooked hams. The combined use of pelvic suspension and high voltage ES appeared to have no additional positive effect (Dransfield et al., 1991; Taylor, Perry, & Warkup, 1995). Pelvic suspension and high voltage ES were equally effective in improving tenderness of pork loin in the studies of Dransfield et al. (1991) and Taylor, Perry, and Warkup (1995), but pelvic suspension is advantageous over high voltage electrical stimulation since it results in lower drip loss.

3.3.4.7. Processing of pork. Traditionally, pig carcasses are not divided into primal cuts until overnight chilling. Nevertheless, hot boning or pre-rigor excision, followed by packaging, can be an energy saving process, with less evaporative weight losses and thus an increased yield of saleable meat (Pisula & Tyburcy, 1996; Smulders & van Laack, 1992). However, hot boning implicates an increased risk for excessive rigor contraction because of an increased surface of the carcass muscle exposed to the colder environmental temperature (which can be

counteracted by ES or by conditioning) and increased shape distortion since bones give structure to meat cuts (Pisula & Tyburcy, 1996; van Laack & Smulders, 1989). In an experiment of Iversen, Henckel, Lartsen, Møllao, and Møller (1995) muscle shortening of 27% was found in cuts excised at 1 h post-stunning, while delaying boning to 6 h post-stunning reduced cold shortening markedly to only 6%. The reduction in muscle shortening by delayed boning time was not reflected in the length of sarcomeres. On the other hand, delaying boning time to 6 h post-stunning resulted in decreased Warner-Bratzler shear force values, but these values were still relatively high, suggesting considerable cold toughening. In a study of Møller and Vestergaard (1987), both sarcomere shortening and the toughness of *longissimus dorsi* muscles, excised from carcasses with a low pH (pH 45 min post mortem 5.7–6.1), were unaffected by early excision. Carcasses with a high pH (pH 45 min post mortem 6.1–6.5) were more susceptible to cold shortening when excised directly after the chilling tunnel (–28°C–22°C), if no delay times of at least 4 h before chilling, was given. Although some primals are deboned completely, the commercially important pork loins are generally marketed “bone-in”, which has the advantage to be less prone to shape distortions. Neel et al. (1987) found that an accelerated processing system (processing bone-in cuts immediately after rapid chilling), with or without ES, could produce loin sections and retail pork loin chops with water binding capacity, shear values and colour scores, and sensory panel ratings that are equal or superior to conventional controls. They further concluded that the application of accelerated processing systems of this type in the industry could considerably reduce processing time, space and energy, while maintaining or enhancing the current level of pork quality.

3.3.4.8. Conditioning of pork. In contrast to beef and lamb, little attention is paid in current slaughter practice to prolonged (more than 3–4 days) post mortem ageing of pork. During ageing of pork, the proteolytic enzyme activity (calpain proteolytic system; Koohmaraie, 1992) and the structural weakening of the myofibrils, the intermediate filaments and the intramuscular tissues, namely the endomysium and perimysium (induced by calcium ions; Takahashi, 1996) contribute to the tenderization of the meat. According to Takahashi (1996) the tenderization as a result of extended ageing (for pork at +5°C after 5 days) is mainly due to the structural weakening of the intramuscular connective tissues, endomysium and perimysium. Dransfield, Jones, and MacFie (1980) studied the tenderization in the *m. longissimus dorsi* of different species during conditioning at +1°C. The decrease in toughness was effectively described by an exponential decay equation. The average rate constant was 0.40 days⁻¹ for pork, 0.21 days⁻¹ for

lamb and 0.17 days⁻¹ for beef, veal and rabbit. For pork, 50% on average of tenderising occurred within 2 days and 80% in 4.9 days, while for beef, veal and rabbit 4.2 and 9.5 days, respectively, were necessary. At the completion of tenderising, pork was the most tender and beef and rabbit were the toughest, whilst the difference between the initial and the ultimate tenderness was largest for beef and lamb. Taylor, Nute, and Warkup (1995) demonstrated that ageing of vacuum packed pork samples (*m. longissimus thoracis et lumborum*) at +1°C from 4 to 7 days and further to 12 days improved tenderness as estimated by taste panel as well as instrumentally measured. In an experiment by Wood et al. (1996), conditioning time of 1 day vs 10 days at +1°C of *m. longissimus thoracis et lumborum*, had a bigger effect than breed difference (Duroc vs Large White) and feed level (high vs 0.8×high), reducing toughness and increasing myofibrillar fragmentation index. Tenderness as scored by a trained taste panel on an eight-point scale, was 1.0 units higher in pork conditioned for 10 days compared to 1 day.

Pork flavour intensity and overall liking was increased and the intensity of abnormal flavours decreased by a longer conditioning time. Wood et al. (1996) showed that both tenderness ($r=0.60$) and flavour ($r=0.65$) contribute significantly to overall liking which forms the explanation why longer conditioning times are now common in the UK pig industry. Moreover, Feldhusen and Kühne (1992) found that ultra rapid chilling of pig carcasses (with fast cooling of surface muscle layers to temperatures below the freezing point) did not adversely affect important parameters of tenderness, provided that an ageing period of 2–3 days was ensured. Tough meat as a result of cold shortening induced by hot boning at 1 h post-stunning and followed by chilling in ice water until 24 h post-stunning, could not be overcome by ageing for up to 7 days in an experiment of Iversen et al. (1995). On the other hand, delayed hot boning at 6 h post-stunning can give acceptable tender meat if aged for at least 7 days (at +2°C) (Iversen et al. 1995). In a study of Taylor and Martoccia (1995), electrically stimulated pork became more tender with ageing from 3 days to 10 days (vacuum packaged and stored at +1°C), while no electrically stimulated controls were tougher at 3 days and did not become more tender with ageing up to 10 days.

3.3.5. Preparation before consumption

Additionally, at preparation level, some improvements in the eating quality of pork could be obtained, by giving some cooking advice to the consumers. According to the American Meat Science Association and National Livestock and Meat Board (1978), the recommended doneness temperature for pork is 75°C. Wood, Nute, Fursey, Cuthbertson (1995) found that in the case of grilling steaks, an intermediate final tem-

Table 14
Division of sows according to breed in Belgium (in %)^a

in %	Landrace	Hybrids	Piértrain	Large White	Others
1990	17.5	14.8	4.7	2.3	5.8
1992	62.3	22.0	5.2	2.9	7.6
1994	51.1	28.0	3.8	3.0	11.0
1995	51.9	31.7	3.6	2.8	10.1
1996	46.0	36.4	2.3	2.3	11.9
1997	41.8	39.3	3.0	2.9	12.9
Evolution	↘	↗	↘	≈	↗

^a Nationaal Instituut voor Statistiek, 1998.

perature (72.5°C) is most appropriate, producing more tender and juicy meat than the higher temperature (80°C) and more flavoursome meat than the lower (65°C). In the case of roasts (cooking in an oven at 170, 180 and 190°C, followed by roasting on foil-covered enamel trays until internal temperature of 65, 72.5 and 80°C) cooking to a “well done” state gave optimal eating quality. Tenderness and juiciness were less affected by final temperature and flavour scores were improved at the highest temperature.

4. Conclusions and implications

The fact that consumers are increasingly concerned about health and food-borne health risks, as well as increasingly interested in production and processing methods, urges for adequate response strategies by agribusiness and food companies. Consumption figures indicate that fresh meat consumption is under pressure. Despite a favourable long-term evolution for pork, a decrease in fresh pork consumption has been noticed during recent years. Consumer research into perceptions of and beliefs related to fresh meat, reveals that pork scores worst as compared to its main fresh meat substitutes, beef and poultry, on “leanness”, “healthiness” and attributes that relate to eating or sensory quality.

The comparison of consumer perception and facts related to nutritional value and healthiness of pork confirms the occurrence of bias between scientific indicator criteria and their perception (Kramer, 1990; Den Ouden et al., 1998). Pork seems not to deserve the worst perception based on actual fat content, cholesterol content or its fatty acid profile. Despite the strong association of pork with fat and unhealthy, it is indicated that pork can be very poor in fat and cholesterol depending on the specific meat cut. The increasing health consciousness of consumers has yet been translated in selection for leaner pig breeds and a lean meat-rewarding carcass grading system. Eales and Unnevehr (1988) have indicated that consumers allocate expenditures among meat products, i.e. specific meat cuts or meat

preparations, rather than among meat from different species. The perceived shifts in demand are assumed to result from both increasing health concerns and convenience motives. A shift away from choices between meat aggregates at consumer level implies the necessity of consumer-oriented product development, as well as communication around specific cuts rather than meat types. Effective and reliable communication emerges since a lack of information or misinformation about nutrients and overall healthfulness are frequently referred to as the major causes of meat image decline (Khan et al., 1995; von Alvensleben, 1995). However, reliable communication requires first acceptable products, which can only be developed based on intrinsically perfect and safe raw materials.

Different possibilities to improve the intrinsic quality of fresh pork are identified. Nutritional value and health aspects can be improved through adapting the pig diet composition. The enrichment of pork fat with PUFA, whether of the (*n*-6) or (*n*-3) series is feasible without detrimental effects in terms of sensory acceptability. Cured meat products are more demanding, especially when the amount of (*n*-3) fatty acids in the pork fat is elevated. Considerable efforts through selection programmes have positively influenced carcass leanness, which is clearly identified as another factor of concern for the consumer.

Besides possibilities to improve nutritional value and health aspects, attention has to be paid to eating and sensory quality parameters, since the general perception of pork taste and tenderness is also worst as compared to beef and poultry. In parallel with selection programmes for leaner carcasses, the incidence of stress susceptibility has also been increased, resulting in poorer meat quality and reduced animal welfare. Fortunately, during the last decades, selection goals became more extended, comprehending, apart from animal performance and carcass quality, also stress resistance and meat quality properties. Consumer orientation in breeding implies the need for further focus in future selection programmes on meat quality characteristics. The results of the eating quality preference tests implicate that a shift in the Belgian pig population from the homozygous stress susceptible cross of Piétrain boar x Belgian Landrace sow to the heterozygous stress negative cross of Piétrain boar x hybrid sow is a step forward towards improving the eating quality of pork. This evolution has already been going on for some years and since 1996, the Landrace breed in the Belgian sow population dropped below 50% in favour of hybrid sows (Table 14).

In comparison to potential improvements resulting from genetics, only small profits for intrinsic pork quality can be gained from modifications at farm level. A shift towards no castration of male pigs includes potential economic, animal welfare and environmental benefits, as well as perspectives related to carcass

leanness. However, in absence of reliable screening methods for boar taint, a complete or even part switch from castrated to entire male production remains utopia.

Neither major sensory improvement nor deterioration can readily be expected by dietary modifications. A similar conclusion can be drawn related to pig production conditions as regards the feeding and housing system. Strategies that include alternative feeding or housing do not include possibilities towards improving intrinsic health and sensory meat characteristics. Preferences for meat from less intensive livestock production are driven by perceptions of extrinsic rather than intrinsic product characteristics. Oude Ophuis (1994) showed that free-range labelling of pork resulted in a positive connotation, however only for consumers that had prior experience with free-range pork; thus for consumers who had already a positive attitude towards free-range pig production. The main reason to opt for free-range pig production, is ethics and animal welfare.

Transport and handling before slaughter are of utmost importance to meat quality. Good manufacturing practices include benefits that are in the interest of every party involved: the producer, the slaughterhouse, the consumer and the animal. Meat quality of pork can be considerably improved through respecting a recommended feed withdrawal period and lairage time prior to slaughter and appropriate stunning. Additionally, less conventional and currently not practised post-slaughter handling techniques dealing with chilling, electrical stimulation, hanging, shackling, deboning and conditioning, can significantly influence meat tenderness and hence its overall acceptability.

The identified possibilities to improve nutritional value, healthiness and eating quality include several trade-offs which can be made. Besides the different factors that are highlighted in this paper, economic implications for all participants of the pork chain, including the consumer, as well as impacts on extrinsic product cues like animal welfare and the environment, have to be monitored. Succeeding in the major task for slowing down or reversing the unfavourable consumption evolution requires co-operation and quality management throughout the entire pork chain. This implies that every stage delivers exactly that product that is the ideal product for the next stage to work with. The challenge is not only to deliver products with acceptable characteristics, but also to limit and guide the natural variability of the product. As one link fails to deliver products with uniform quality levels, negative impacts on processes and consumer acceptability can be expected. A final challenge will inevitably deal with further consumer-oriented research and with the translation of the realised improvements into effective pork marketing and communication with the end consumers.

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